Lecture 20 Problem – Maximum undistorted power (1)

$$\overline{P_{RL}} = V_{RMS}\, I_{RMS} = \overbrace{\frac{1}{\sqrt{2}} V_P \cdot \frac{1}{\sqrt{2}} I_P}^{\text{Sinusoidal signal}} = \frac{1}{2}\cdot\frac{V_P^2}{R_L}$$

V_P: Peak value of the ac signal

The maximum undistorted power transferred to a load is the average power transferred to a load when the signal across the load is undistorted.

The maximum undistorted signal can be calculated using the cut-off and the saturation limit and selecting the minimum value between the 2.

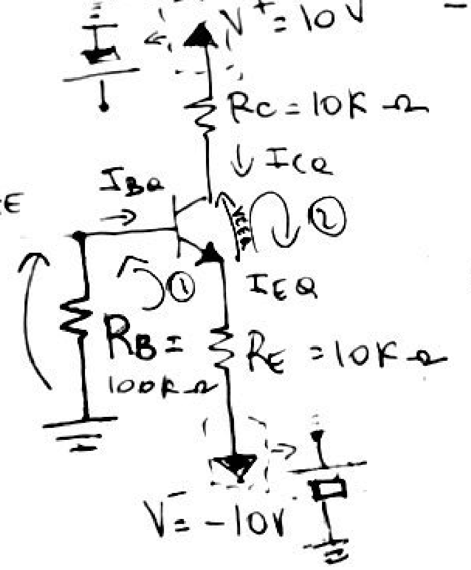
$$V_p = \frac{V_{PP}}{2} = 2 I_{CQ} r_C \quad \text{(Cut-off limit)}$$

$$V_p = \frac{V_{PP}}{2} = 2 V_{CEQ} \quad \text{(Saturation limit)}$$

In order to determine V_p we need to calculate I_{CQ}, V_{CEQ}, and r_C (the inverse of the slope of the ac load line).

DC CIRCUIT

ASSUME THE BJT TO OPERATE IN THE FORWARD-ACTIVE REGION



KVL @ ①

$$-R_B I_{BQ} - V_{BE(on)} - R_E \overset{(\beta+1)I_{BQ}}{I_{EQ}} - V^-$$

$$I_{BQ} = -\frac{V^- + V_{BE(on)}}{R_B + (\beta+1) R_E} = \frac{-V^- - V_{BE(on)}}{R_B + \beta+1\, R_E} = \frac{10 - 0.7}{100 + 101\cdot 10} = 0.00838\,mA$$

$I_{CQ} = \beta I_B = 0.838\,mA$ $\quad I_{EQ} = 0.846\,mA$

KVL @ ②

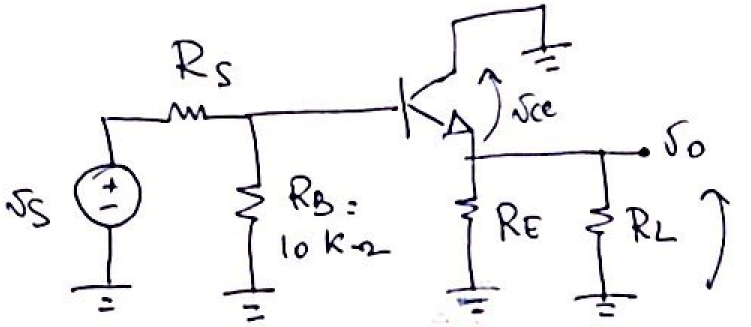
$$V^- + R_E I_{EQ} + V_{CEQ} + R_C I_{CQ} - V^+ = 0$$

$$-20 + 10 * 0.864 + V_{CEQ} + 10\cdot 0.838 = 0$$

$V_{CEQ} = 3.16\,V > V_{CE,SAT} = 0.2V$

The assumption of the BJT being in F.A region is verified

Next step is to determine r_c. In order to do that, we need to sketch the AC circuit.



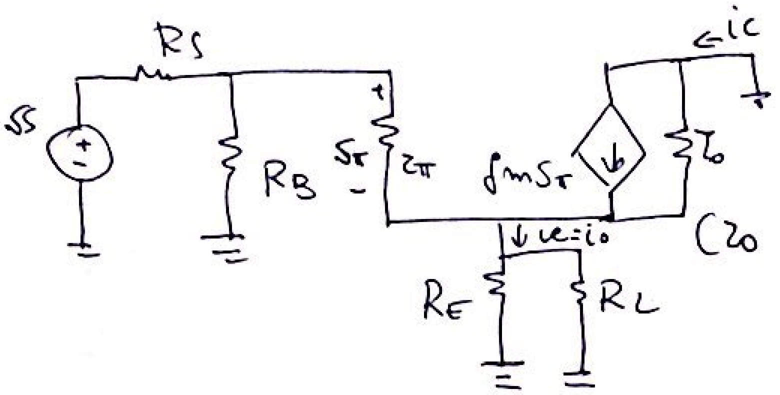
$$r_C = \left| \frac{v_o}{i_o} \right|$$

ac only

ac only

$$i_o = \frac{v_o}{R_E // R_L // r_o}$$

ac only



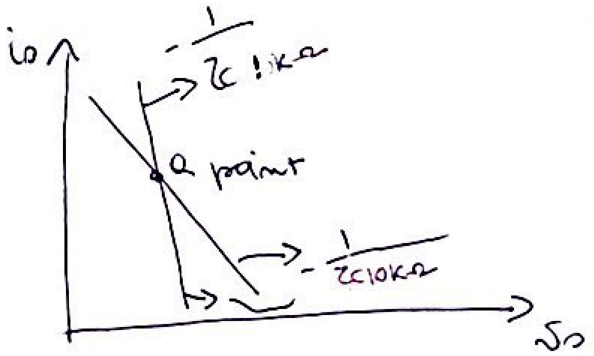
$r_c = R_E // R_L \;\; r_o$

(r_o is in parallel with $R_E // R_L$)

$$r_o = \frac{100}{0.838} = 115\,k\Omega$$

$r_{c_{1k\Omega}} = 0.502\,k\Omega$

$r_{c_{10k\Omega}} = 4.8\,k\Omega$



$R_L = 1\,k\Omega$

$$V_p = \frac{V_{pp}}{2} = \underbrace{0.502\,k\Omega}_{r_{c1k\Omega}} \cdot \underbrace{0.838\,mA}_{I_{CQ}} = 0.756V \text{ (cut-off-limit)}$$

$$V_p = \frac{V_{pp}}{2} = \frac{2 \cdot 3.16}{2} = 3.16V \text{ (saturation limit)}$$

$$\overline{P}_{R_L=1k\Omega} = \frac{1}{2}\frac{(0.756)^2}{1k\Omega} = 0.286\,mW$$

$R_L = 10K\Omega$

$V_p = \frac{V_{PP}}{2} = 4.8k \cdot 0.838m = 4.02V$ (Sat. limit)

$V_p = \frac{V_{PP}}{2} = 3.16V$ (Cut-off limit) ←

$\overline{P_{RL}} = \frac{1}{2}\frac{(3.16)^2}{10k} = 0.499\,mW$

$\overline{P_{RL=1k\Omega}} = 0.286\,mW$; $P_{RL=10k\Omega} = 0.499\,mW$

More understanded power can be tranferred to a higher load. This could be immediately understood by looking at the ac load lines in the two cases. For the higher load, the ac load line has a lower slope which yields a larger voltage swing.